



NASA DFRC Practices for Prototype Qualification

William Lokos

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Outline

- Introduction
- Overview of Some UAV's, RPV's and Manned Prototypes Flown at DFRC
- Basic Safety of Flight Considerations and Available Processes
- Frequently Used Standards and References
- Typical Safety-of-Flight Approaches
- Other Considerations
- Summary

NASA DFRC's Mission

- The National Aeronautics and Space Administration is a civilian agency
- NASA was created from the National Advisory Committee for Aeronautics, NACA
- The Dryden Flight Research Center originally began as an offshoot of the Langley Research Center
- DFRC is the agency's premier flight research center and is located at Edwards AFB California

Air Vehicles Flown at DFRC

- UAV's
- RPV's
- Manned Prototypes
- Other

Mini Sniffer



Drones for Aerodynamic and Structural Testing



DAST Wing Flutter Testing



Spin Research Vehicle



Highly Maneuverable Aircraft Technology



HiMAT



PA-30 Twin Comanche



Controlled Impact Demonstrator



CID Touch Down



CID Post Impact Fireball



CID Video From Website

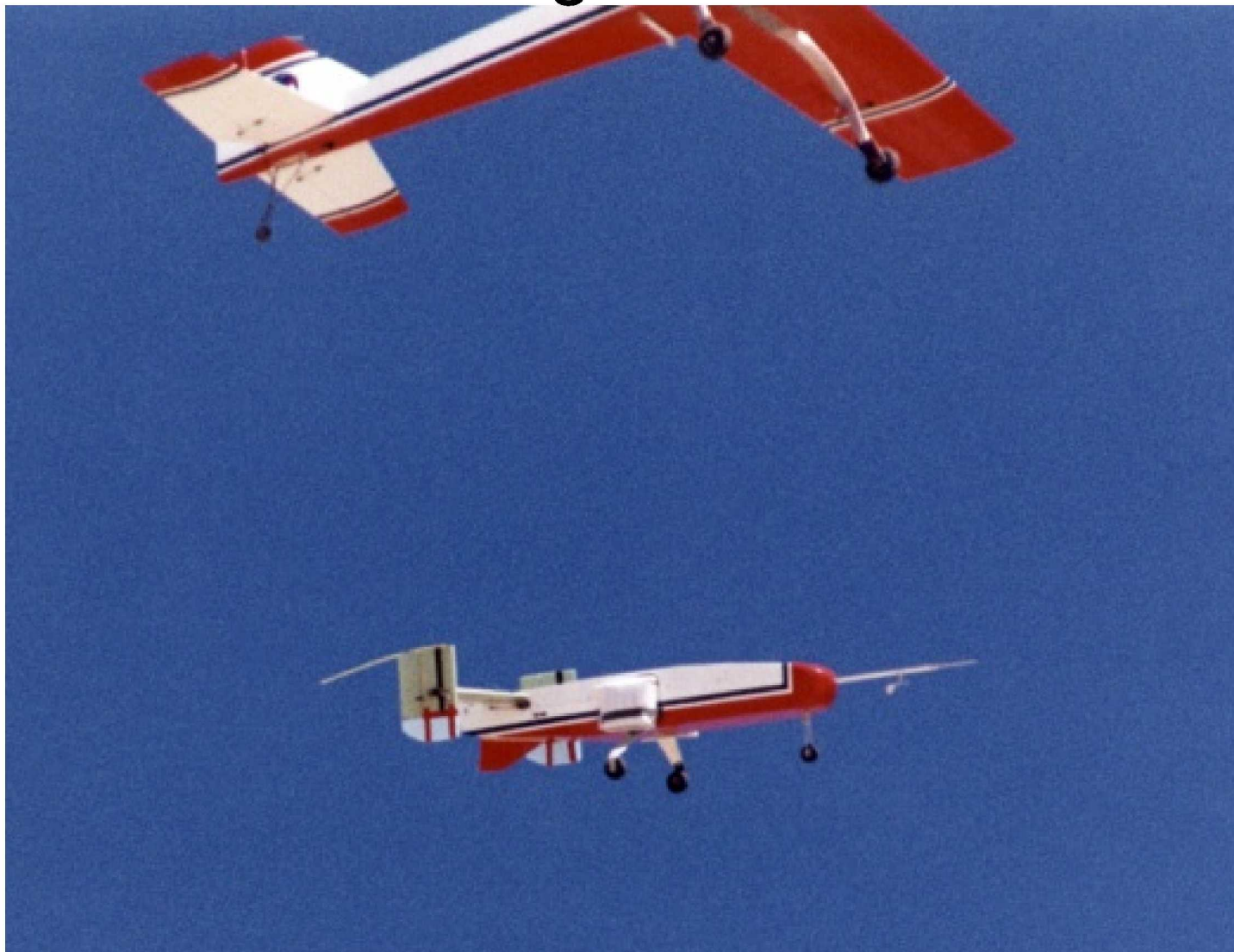
X-36



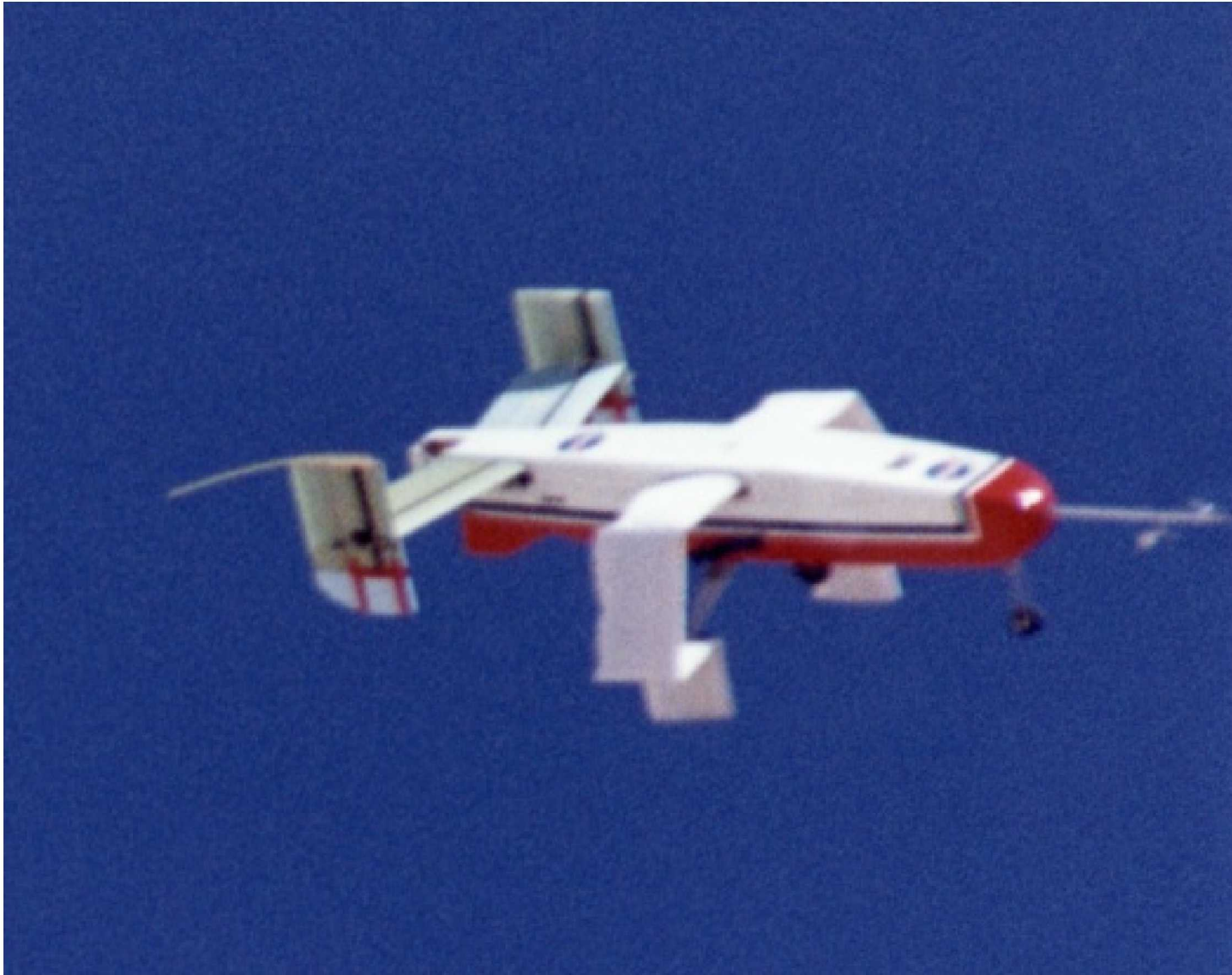
Inflatable Wing Demonstrator Being Carried Aloft



Inflatable Wing Aircraft Release



Wing Inflation



Inflated Wing in Controlled Flight



Autonomous Soaring Demonstrator



Autonomous Formation Flight



Automated Aerial Refueling Research



Autonomous Airborne Refueling Demonstrator



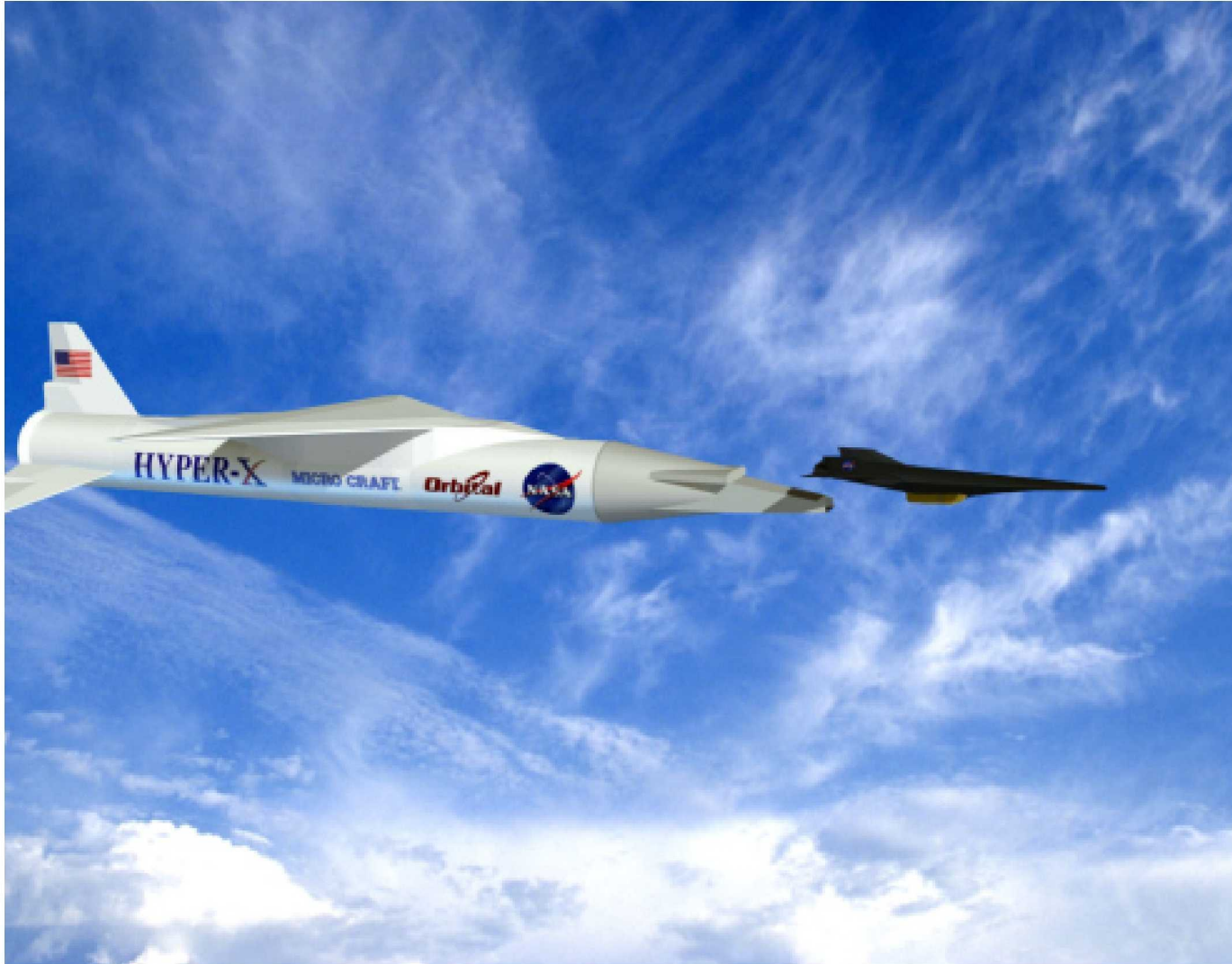
X-45A



Pegasus Light Satellite Launcher



X-43A Hyper-X Illustrated Separation



Hyper-X Being Carried Aloft



Hyper-X Release



Hyper-X Booster Ignition



ERAST Demonstrator 2 (D-2)



Perseus B



Theseus



Proteus



Rans S-12 RPV Takes Off with Spacewedge



Spacewedge Landing



X-38 Crew Return Vehicle after Release



X-38 Landing



APV-3 Networked UAV Teaming Experiment



APV-3's



Helios



Altus II



Altair on a Fire Mapping Mission



IKHANA



X-48B Blended Wing Body



Global Hawk



Basic Safety of Flight Considerations

- You don't want it to break!
- So, you want the working strength to equal the max operating load.

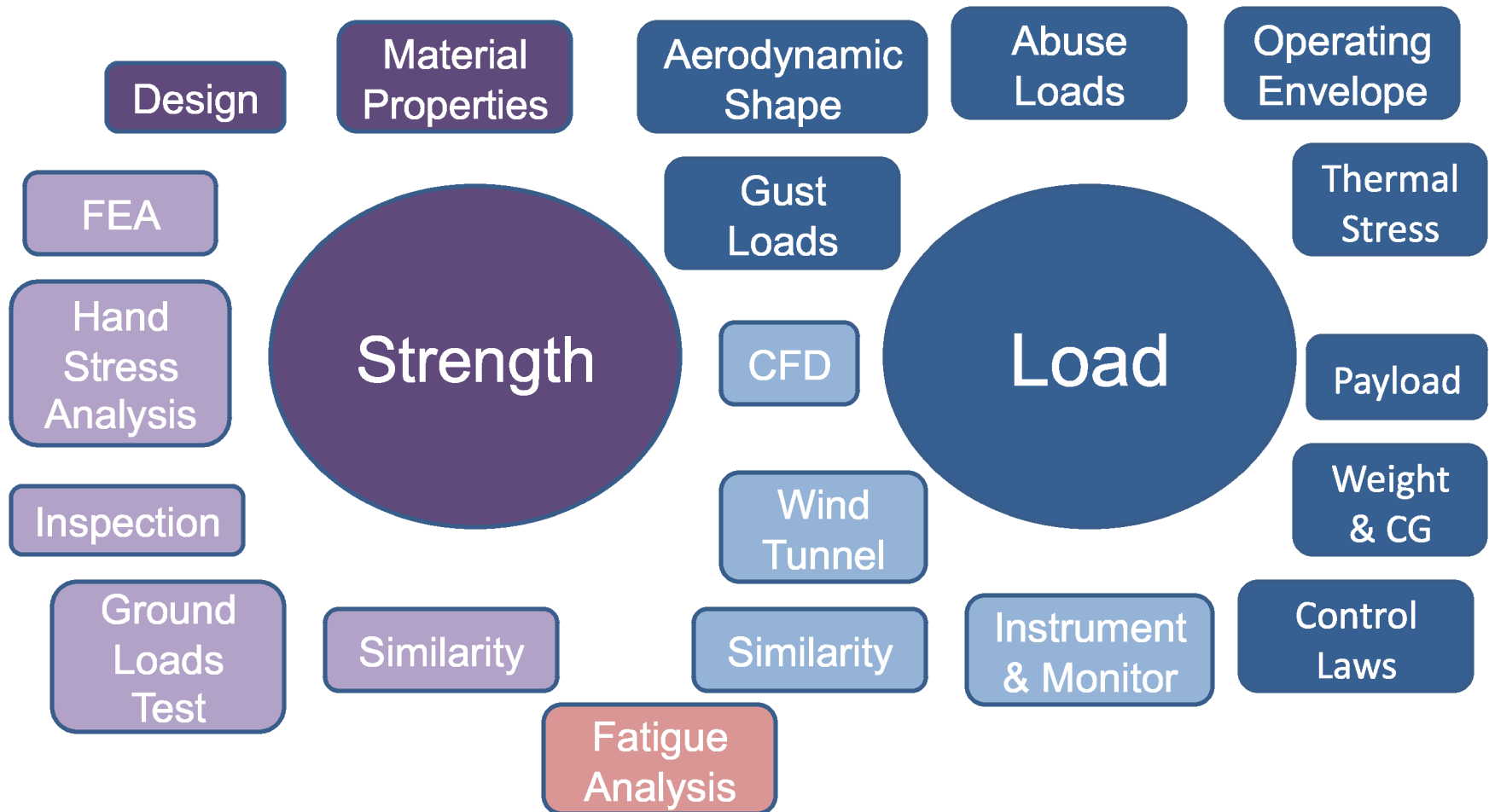
Basic Considerations for Strength

- Traditional Design FS of 1.5 was probably developed from the ratio of F_{tu} to F_{ty} of mild steel
- The F_{tu}/F_{ty} ratio alone may have been acceptable for mild steel design as the toughness of mild steel covered stress concentration and fatigue issues
- For 7075 T6 aluminum alloy $F_{tu}/F_{ty} = 1.1$ and we know this does not cover stress concentration and fatigue issues
- Therefore with modern materials we rely on empirically based design guidelines

Standards and References

- NASA-STD-5001 “Structural Design and Test Factors of Safety for Space Flight Hardware”
- DHB-R-001 “Structural Design, Proof Test, and Flight Test Envelope Guidelines”
- DHB-R-006 “DFRC Flight Research Design Preparation Handbook”
- DHB-X-001 “Airworthiness and Flight Safety Review, Independent Review, Mission Success Review, Technical Brief and Mini-Technical Brief Guidelines”
- DCP-S-052 “Flight Termination System Requirements”
- DCP-S-002 “Hazard Management Procedure”
- FAR Parts 23 and 25 Reference
- Mil STD 8860 Reference
- Mil-A-8591 Reference

Required Knowledge and Available Processes



NASA DFRC Guidelines for Structural Design, Proof Test and Flight Test Envelope

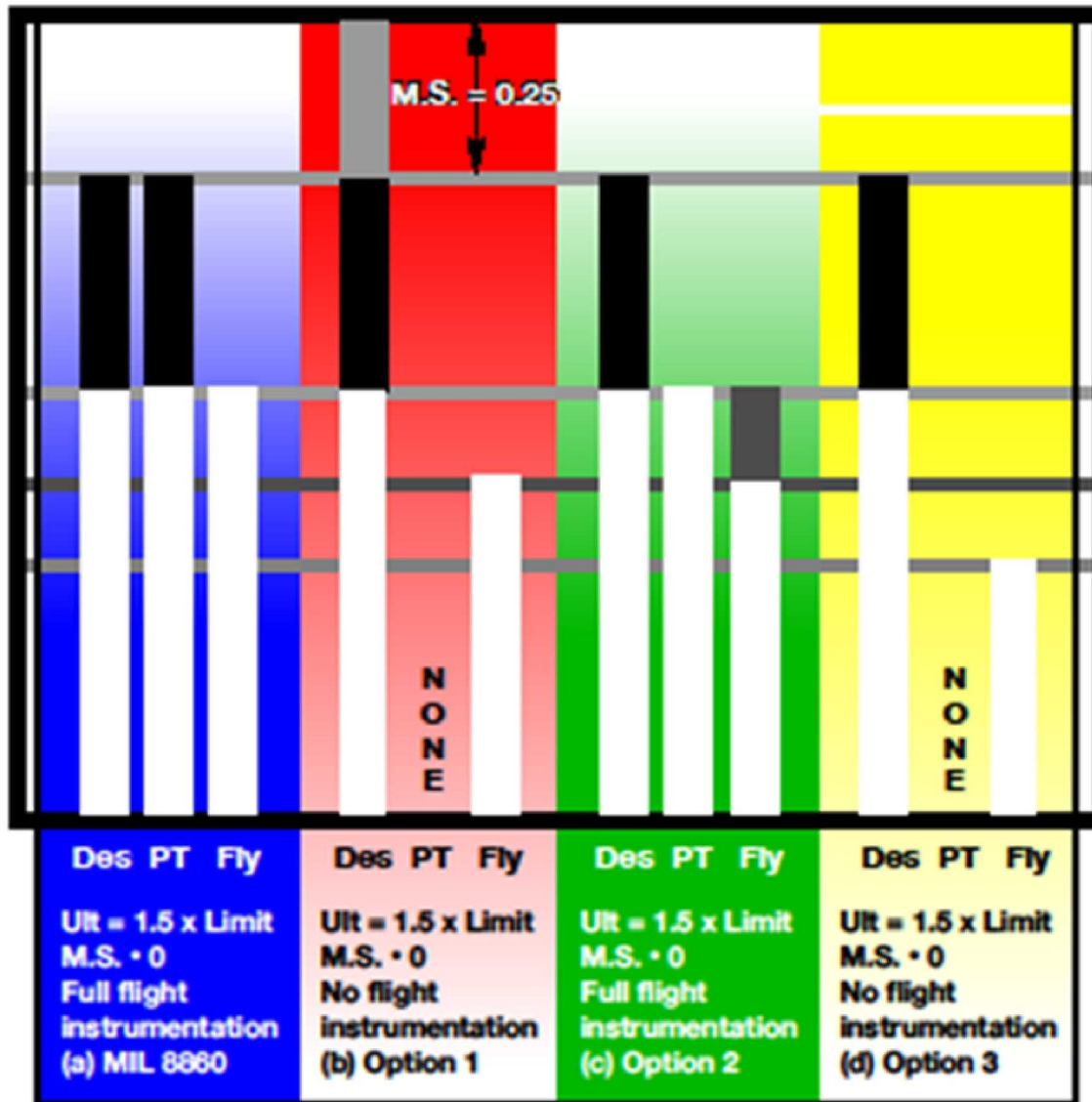
Failure for
M.S. = 0.25

Ultimate
(Failure for
M.S. = 0)

Limit

80% limit

60% limit



- Load limit
- Load Ultimate (F.S. = 1.5)
- Load for M.S. = 0.25 (F.S. = 1.5)
- Operation on case by case basis

Ultimate = (F.S.) x Limit
M.S. = Allowable/Ultimate - 1
F.S. = Factor of Safety
M.S. = Margin of Safety
Des = Design
PT = Proof Test

Typical Safety-of-Flight Approaches

- Proven Aircraft
- New Prototype Design from Scratch
- Modified Aircraft
 1. New shape
 2. New control laws
 3. New operating envelope
 4. Limited scope add-on or substitute structure
 5. Extensively modified or replaced structure

Proven Aircraft

Examples: F-104, F-18, Predator-B, B-720

- Usually already designed and tested per Mil Std or FAR
- Operate within established envelope

All New Prototype Design

Example: X-29A

- CFD and Wind Tunnel Load Predictions
- Design to 1.875 Factor-of-Safety
- Install Structural Load Instrumentation
- Ground Load Test to ~110 % Design Limit Load (proof test and strain gage calibration)
- Fly to 80% DLL
- Post-flight Structural Inspections
- Expand Envelope Through Real-Time Monitoring
- Designed for 300 Hour Fatigue Life

X-29A



1) New shape

Examples:

DAST-ARW1, F-8 Super Critical Wing, AFTI/F-111
MAW

- Predict New Loads
- Installed Load Measurement Instrument
- Ground Load Calibration Test
- Load Test (driven by the structure also being new)
- Real-Time Monitor
- Post Flight Inspections

DAST ARW-1



F-8 Supercritical Wing



AFTI F-111 Mission Adaptive Wing



2) New Control Laws

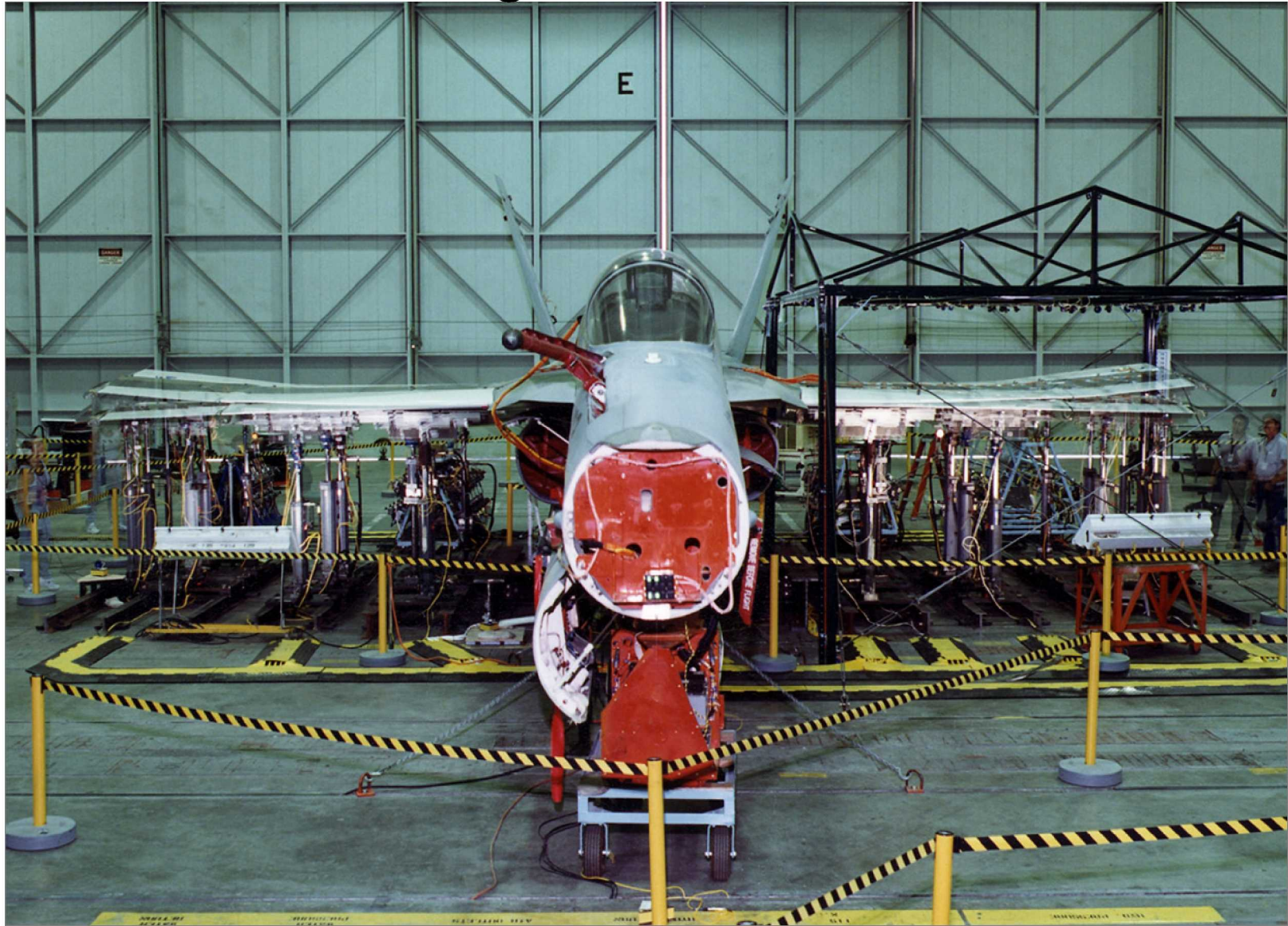
Example: AAW F-18

- Installed Load Measurement Instrument
- Ground Load Calibration Test
- Real-Time Monitoring Against Established Component Load Limits
- Post-Flight Inspections

Active Aeroelastic Wing F-18



AAW Strain Gage Loads Calibration Test



AAW Loads Calibration Test Video (from Website)

3) New Operating Envelope

Example: F-18 HARV

- Instrument
- Real-Time Monitoring
- Post-Flight Inspections

F-18 High Angle of Attack Research Vehicle



F-18 HARV with Thrust Vectoring



F-18 HARV Engine Run



4) Limited Scope Add-On or Substitute Structure

Examples: SR-71 LASRE, ECLIPSE, F-16XL
SLFC

- Predict Loads
- Design New Structure to 2.25 DLL
- Post-Flight Inspections
- Some Instrumentation
- Some Structural Sub-Component Load Tests
- Real-Time Monitoring
- Minimal Fatigue Consideration

Linear Aerospike SR-71 Experiment (LASRE)



Eclipse QF-106



Tow Hook Release Mechanism



Eclipse Aerotow Research Flight



F-16XL Supersonic Laminar Flow Control



5) Extensively Modified or Replaced Structure

Example: SOFIA B747SP

- CFD and Wind Tunnel Load Predictions
- Design to 1.5 Factor-of-Safety
(With 10% material property knock down)
- Incrementally Validated FEM
- Install Extensive Structural Strain Instrumentation
- Baseline Flight Strain Survey
- Limited Ground Load Tests
(Cabin pressure test, jacking test, door test)
- Expand Envelope Through Real-Time Monitoring
- Post-Flight Structural Inspections

Stratospheric Observatory For Infrared Astronomy



SOFIA with Telescope Cavity Open



Non-Structural Mitigations

- Restricted Test Range
- Flight Termination System
- Hazard Analyses
- Independent Technical Review

Prototype Failure Causes

- Control System
 - Electronic Sub-Components
 - Mechanical Components
 - Software
 - Loss of Command Link
 - Sensors
- Other Causes
- Few Structural Related Catastrophic Failures

Concluding Comments

- A variety of combinations of structural processes can be used to produce good results
- Basic material properties limit the minimum design factor-of-safety that can be chosen
- Flight Terminations Systems do not always work
- Aircraft can leave controlled airspace
- Control systems can dominate structural loads
- Hazard analyses are great tools to identify weak links
- “Stakeholder” risk tolerance levels play a part in the big picture

Summary

- NASA DFRC uses Standard and Ad-Hoc Combinations of
 - Design Factors-of-Safety
 - Analyses
 - Ground Tests
 - Instrumentation and Monitoring During Flight
 - Inspection
- Hazard Analyses are Useful
- Airspace Restrictions
- Flight Termination Systems
- Independent Review and Management Approvals
- Catastrophic Structural Failures are Rare